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CHEMICAL CHARACTERISTICS OF LAKES IN THE TRUELOVE LOWLANDS, DEVON ISLAND, NORTHWEST TERRITORIES

Inland Waters Directorate
Western and Northern Region

Direction générale des eaux intérieures
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Canada

CHEMICAL CHARACTERISTICS OF LAKES IN THE TRUELOVE LOWLANDS, DEVON ISLAND, NORTHWEST TERRITORIES

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ABSTRACT

A unique opportunity was provided in 1985 to obtain characterization of the chemistry of surface waters of Truelove Lowlands, Devon Island, Northwest Territories. The ionic composition of seven lakes in the lowlands are described and discussed as regards their sensitivity to acidic deposition. A comparison of field and laboratory analyses is made drawing attention to possible inaccuracies in technology and/or the change in sample integrity over time. Metal residue concentrations in water, lake sediment and snow are presented and reference is made to efforts to collect and quantify organochlorine residues in freshwater shrimp (Lepidurus sp.). Sediment samples from the lakes are described with respect to metal concentrations and their toxicity to a mixed culture phytoplankton population.

Caractéristiques Chimiques des lacs des Basses-Terres de Truelove,

Ile Devon, T.N.-O.

(D. Gregor et Wm. D. Gummer)

Résumé

En 1985, on a pu profiter d'une occasion unique d'obtenir une caractérisation de la chimie des eaux superficielles présentes dans les basses-terres de Truelove, dans l'île Devon (Territoires du Nord-Ouest). On décrit la composition ionique de l'eau de sept lacs des basses-terres, et l'on examine le lien entre la composition et la sensibilité des lacs aux précipitations acides. Tout en comparant les résultats des analyses in situ et des analyses en laboratoire, on insiste sur les inexactitudes qui peuvent se manifester au cours du temps, du point de vue de l'application des méthodes et des modifications que peut subir l'échantillon. On indique les concentrations métalliques résiduelles relevées dans l'eau, les sédiments lacustres et la neige, et l'on mentionne les efforts déployés pour recueillir et quantifier les résidus organochlorés présents dans les crevettes d'eau douce (Lepidurus sp.). On indique la teneur en métaux des échantillons de sédiments prélevés dans les lacs, et leur toxicité pour une population phytoplanctonique cultivée, de caractère mixte.

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INTRODUCTION

The Northwest Territories (NWT) are large and remote. In the recent past, it has been assumed that this remoteness would protect the natural environment of the north from anthropogenic pollution. However, as the acid rain story has unfolded, it has become evident that distance from a source of environmental contamination, particularly those sources that are emitting to the atmosphere, is not a guarantee of safety from anthropogenic contamination. This is especially true for chemically stable organic toxicants, metal compounds and acid precursors which can be transported extremely long distances over long periods of time and still be of concern upon deposition.

Graphitic carbon, an indicator of the presence of anthropogenic contaminants, and the actual measurement of organic compounds within the Arctic atmosphere have been the subject of a number of related studies and subsequent reports discussing the phenomenon of Arctic haze (Hoff and Barrie (1986); Heidam (1984); Rahn and Shaw (1982); Carlson (1981); Rosen, et. al. (1981); and Barrie, et. al. (1981)). The study of contaminants in the Arctic has not been limited to the atmosphere. McNeely and Gummer (1984) investigated the chemistry of snow-pack and surface water samples from east central Ellesmere Island between 1979 and 1981. The presence of organochlorine pollutants in Arctic marine mammals, fish and polar bears has been reported by Norstrom et. al. (1985) and by Muir et. al. (1985).

More recently, the sensitivity of the northern environment to acidic deposition has received attention. The sensitivity of the terrestrial environment has been mapped and discussed in a recent report by Lucas (1985). Similarly, the sensitivity of the aquatic environment has been mapped for the Western Arctic (Mackenzie District) and Eastern Arctic (Keewatin District) of the Northwest Territories by Tibbatts et. al. (1987). It is evident from both the terrestrial and aquatic maps that large portions of the NWT are sensitive due to limited buffering capacity. The areas of greatest sensitivity are those in which the Canadian Shield is exposed.

The remoteness of the High Arctic prevents the implementation of broadly based environmental surveys of the kind necessary to overcome the information gaps identified. Consequently, Environment Canada, Inland Waters Directorate (IWD), has adopted the approach of specialized surveys and opportunistic sampling as a means of providing information for these parts of Canada. In 1985, IWD was approached by the Northern Heritage Society to assist with water quality sampling in the Truelove Lowlands area of Devon Island, NWT. In return for the provision of sampling bottles and preservatives and for the cost of analyses and shipping, the samples would be collected by the Northern Heritage Society as part of a field camp in the Truelove Lowlands of Devon Island, following a design that was mutually agreeable. This report summarizes the aquatic quality information collected during the field camp in July and August 1985, from a total of seven shallow lakes in the Truelove Lowlands area of Devon Island.

STUDY DESIGN

The Truelove Lowlands are located in the north central part of Devon Island and as such are remote from permanent settlements (see Figure 1). The field camp was planned to extend from early July to early August, during the open water or essentially late spring and summer seasons in this area. Consequently, a study had to be designed relevant to the aquatic environment at these times and within the logistics of the field camp. Two of the most important considerations in designing the field project were (i) that all equipment had to be portable and yet rugged and (ii) since this was a training program with no water quality personnel in attendance, the techniques had to be straight forward. These factors limited sampling to more conventional techniques. Since the Northern Heritage Society field crew was going to be at the study site during snow-melt runoff, it was decided to investigate the effect of snowmelt on several shallow lakes in the area. Unfortunately, sampling of these lakes in advance of the snowmelt was not feasible. Sampling was to encompass a variety of sampling media.

Each of the seven major lakes in the area were sampled approximately twice per week over the period of the study (July 10 to August 3, 1985) for metals, major ions and physical parameters following field procedures established by IWD (Environment Canada, 1983). Field measurements on the water samples included pH and specific conductance. Sampling procedures consisted of a pseudo-depth integrated water sample from the mid-point of

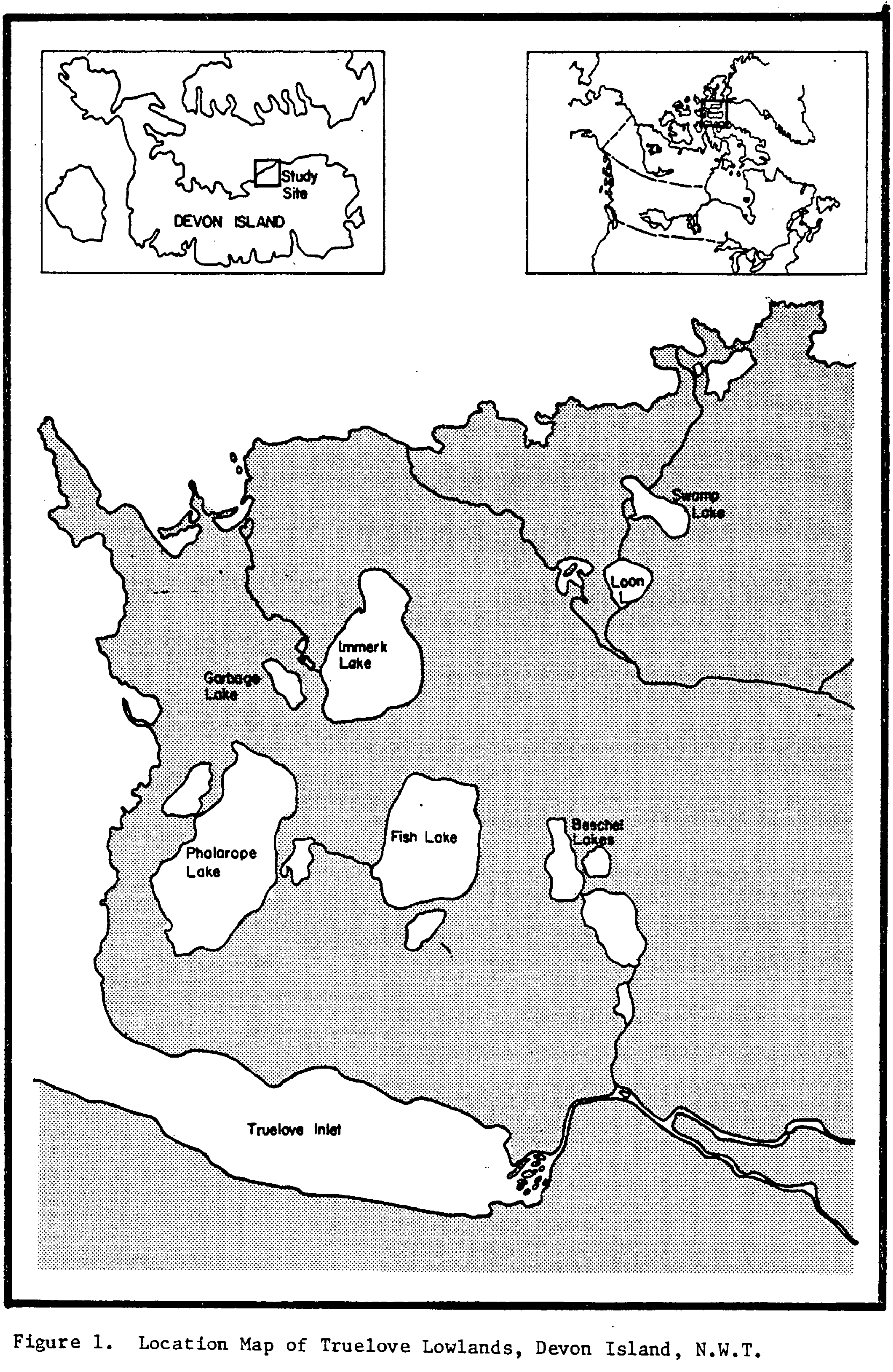

Figure 1. Location Map of Truelove Lowlands, Devon Island, N.W.T.

the lake using pre-cleaned bottles which were subsequently double rinsed with sample water. A single one-litre sample in polyethelene was taken for physical and major ion chemistry. A second one-litre sample in polyethelene was taken for metals. This sample was preserved with 2 ml of concentrated HNO_3. All samples were kept cool until they were air-freighted to the IWD laboratories in Saskatoon, Saskatchewan, and Burlington, Ontario. Details of container cleaning procedures and analytical procedures can be found in Environment Canada (1983, 1985).

The bottom sediments of four of the largest lakes were sampled once during the study. The four lakes sampled were Immerk, Loon, Fish and Phalarope. The sediments were collected from the deepest part of the lake using a sediment dredge. Subsamples of the top 2 cm of sediment were placed in pre-cleaned containers, frozen and shipped to Regina, Saskatchewan. Samples were collected in triplicate at each site with storage of samples in both teflon and polyethelene containers to be used for the determination of organochlorine compounds and metals, respectively. The teflon containers were washed, double rinsed with acetone and hexane and baked for eight hours at 225°C. The polyethelene containers were washed, rinsed with dilute acid and repeatedly rinsed with distilled water. All containers were sealed for shipment and were not opened until used in the field.

Sediment samples from Loon and Fish Lakes were also submitted for testing of their effect on a mixed culture phytoplankton population. This bioassay technique is described by Munawar et al. (1986).

Finally, a species of freshwater shrimp (Lepidurus sp.) abundant in these lakes, were collected from three of the lakes with a minimum of three samples of 25 g per sample. These samples were stored in acetone and hexane-rinsed, oven-baked tinfoil for future investigations regarding biouptake of selected synthetic organic compounds.

RESULTS

A summary of the water chemistry data (physical characteristics and major ions) for each of the seven lakes is presented in Table 1. Detailed results are presented in Appendix I. In general, the lakes tended to be alkaline except during early snow melt period when on the basis of field pH results, the lakes tended towards neutral or slightly acidic conditions. The mean pH for the lakes (on the basis of eight samples each) ranged from 7.6 to 8.6 for field pH and 7.8 to 8.4 for laboratory pH. Of the seven lakes, Immerk and Fish Lakes had the lowest mean pH while Garbage Lake had the highest.

Field and laboratory measurements for specific conductance (SC) did not compare well (Figure 2). In some cases, the lab result was 50% of the field result. Mean specific conductance as measured in the field, ranged from a low of 217 usie/cm for Loon Lake to 368 usie/cm for Beschel Lake. In comparison, mean specific conductance as measured at the laboratory for these two lakes ranged from 173 usie/cm to 204 usie/cm, respectively. The difference between the lab and field specific

Table I. Summary of Water Chemistry Data* for Lakes from Truelove Lowlands, Devon Island, NWT

LAKE		FIELD			LAB															
		pH	S.C.	Temp (°C)	Alk	Ca	Mg	F	K	Na	Cl	SiO_2	SO_4	pH	S.C.	Turb	NFR	HCO_3	Hardness	TDS
BESCHEL	($\bar{x}$)	8.0	368	9.0	116.0	23.1	13.3	0.100	0.60	1.9	2.8	1.47	3.2	8.1	216	0.6	1.5	141.0	112.6	116
	(s)	–	38	(4–12)**	15.0	2.7	1.5	0.020	0.10	0.3	0.4	0.61	1.6	–	26	0.1	1.4	18.8	13.0	14
IMMERK	($\bar{x}$)	7.6	266	7.8	70.8	15.1	7.8	0.032	0.54	4.9	8.5	0.40	1.2	7.8	173	0.3	L1.0	83.5	69.7	81
	s	–	61	(1–15)	9.7	1.9	1.0	0.004	0.06	0.7	0.7	0.05	0.6	–	11	0.1	–	12.1	9.0	11
LOON	($\bar{x}$)	8.0	217	8.9	68.5	15.6	6.8	0.025	0.228	1.1	1.9	0.54	1.6	8.1	130	0.6	L1.0	82.0	66.8	69
	(s)	–	54	(2–14)	13.9	2.4	1.2	0.008	0.060	1.4	2.4	0.08	0.7	–	23	0.2	–	18.5	10.8	14
SWAMP	($\bar{x}$)	7.9	229	9.4	75.2	17.2	7.3	0.027	0.23	1.2	1.9	0.55	1.3	8.1	140	0.5	L1.0	91.2	72.9	75
	(s)	–	47	(6–14)	12.7	2.8	1.0	0.005	0.05	1.5	2.3	0.14	0.9	–	25	0.2	–	15.6	10.9	11
GARBAGE	($\bar{x}$)	8.6	303	10.4	64.2	7.8	12.4	0.030	0.80	14.3	22.4	0.28	1.0	8.4	189	0.5	L1.0	77.9	70.4	97
	(s)	–	35	(8–14)	9.8	1.0	1.5	0.010	0.11	9.2	3.0	0.15	0.6	–	25	0.2	–	12.2	8.6	19
FISH	($\bar{x}$)	7.6	293	7.4	80.3	16.8	9.0	0.035	0.56	4.7	8.8	0.44	2.6	7.8	171	0.4	L1.0	96.5	78.8	91
	(s)	–	84	(3.0–10.5)	8.4	1.8	0.8	0.025	0.06	0.4	0.7	0.05	2.3	–	12	0.1	–	11.4	7.8	8
PHALAROPE	($\bar{x}$)	8.2	239	7.4	60.2	12.5	8.2	0.030	0.85	12.4	23.0	0.31	3.2	8.1	156	0.4	L1.0	73.1	65.1	97
	(s)	–	30	(3.0–11.0)	5.6	1.5	1.9	0.010	0.56	15.3	27.8	0.18	3.5	–	21	0.2	–	6.8	10.6	50

* The mean is based on eight samples collected twice weekly between July 10 and August 3, 1985.
** Minimum and maximum observed temperatures

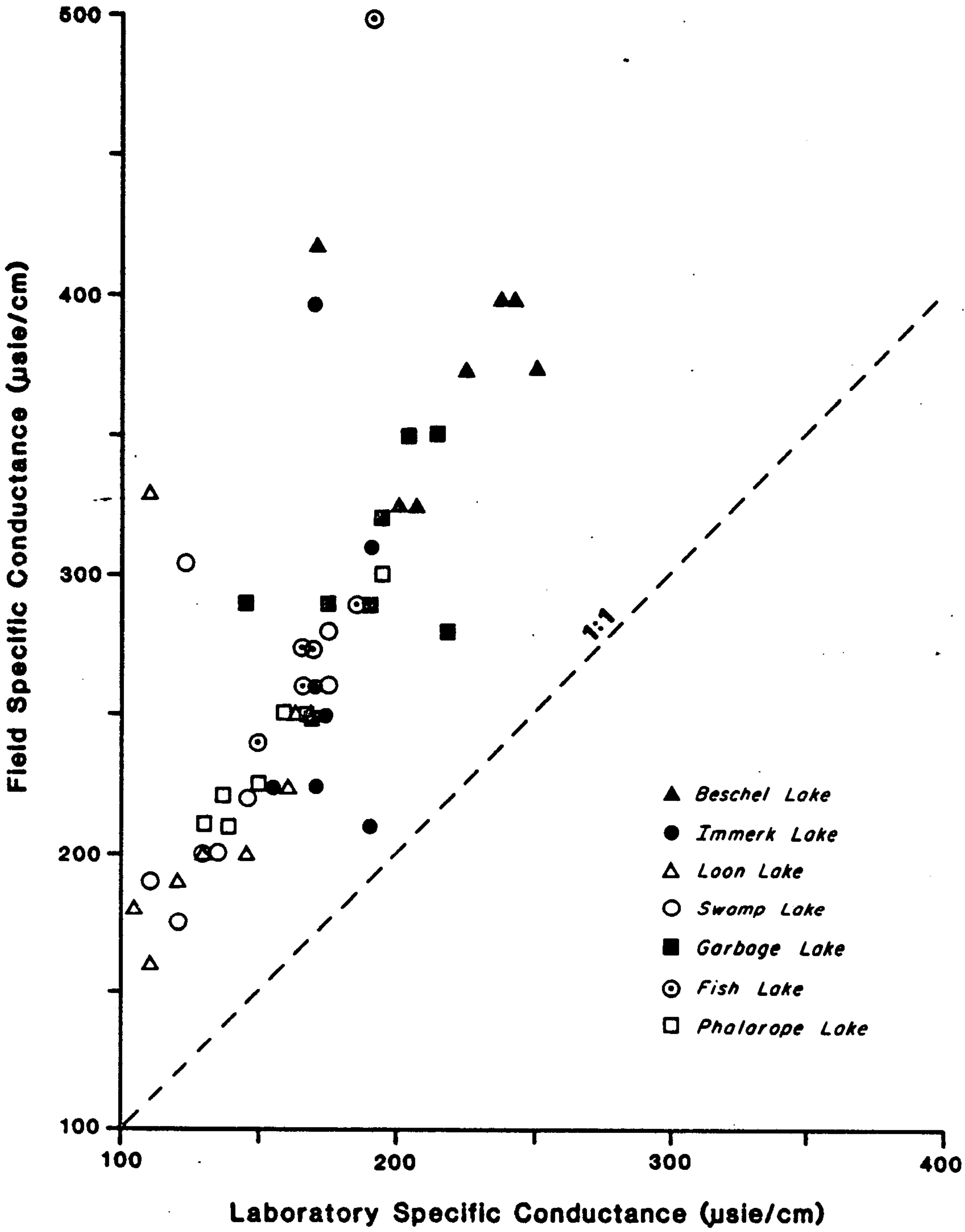

Figure 2. Comparison of Field and Laboratory Measurements of Specific Conductance.

conductance may be a result of changes in solute chemistry over time. Inaccuracies in field equipment may also factor into the difference.

Field water temperature for most of the lakes ranged from just above 0^{o} C to 14^{o} C. At the time sampling commenced in most lakes, the ice was still present but shore leads had opened. Lake water temperatures were beginning to decline by the time sampling was completed. Despite the fact that these lakes were being sampled during and immediately following the snow melt event, it is evident from the turbidity (Turb) and non-filterable residue (NFR) results, that the water was clear throughout the sampling period. Average turbidity never exceeded 1 NTU in any of the lakes while average NFR was less than the detection limit of 1.0 mg/L in all lakes except Beschel Lake, which was only marginally above the detection limit.

Except for iron (Fe), metal concentrations of all lake water samples were either less than or virtually at the detection limit for the analytical methods used (Table 2). Iron existed at a level about one order of magnitude above the detection limit. Zinc (Zn) and Fe were the most common metals detected. Copper (Cu), arsenic (As), and selenium (Se) were periodically detected at a number of the lakes. Garbage Lake had the largest number of metals detected. Loon Lake was the only lake in which lead (Pb) was detected.

The results of total metal analyses of the sediment samples from these

Table 2. Summary of Metals Detected in Lake Water Samples from Truelove Lowlands, Devon Island, NWT

LAKE	METALS (mg/L)	LAKE	METALS (mg/L)
Beschel	*Cu = 0.001 (1)	Garbage	Zn = 0.003 (7)
	Zn = 0.002 (7)		V = 0.0007 (5)
	Fe = 0.04 (1)		As = 0.0001 (2)
			Fe = 0.05 (8)
Immerk	Cu = 0.002 (2)		Cu = 0.002 (3)
	Fe = 0.05 (2)		Se = 0.0001 (1)
	Zn = 0.002 (7)		
	As = 0.0001 (1)	Fish	Zn = 0.002 (8)
			Se = 0.0001 (1)
Loon	Zn = 0.002 (7)		Fe = 0.06 (3)
	Pb = 0.001 (1)		Cu = 0.001 (1)
	Fe = 0.06 (2)		
		Phalarope	Zn = 0.003 (6)
Swamp	Zn = 0.002 (8)		Fe = 0.10 (8)
	As = 0.0001 (1)		

* The value shown is the average of all detected concentrations (if more than 1) followed by the number of values above the detection limit (i.e., the number of observations making up the average).

lakes are presented in Table 3. Aluminum (Al) and Fe are typically dominant in all lakes. This is not surprising as these elements are quite common in the crustal material from which the sediments are derived. Pb was less than detection (50 mg/kg) in all lakes while mercury (Hg) was low but above detection (0.02 mg/kg) in all but Loon Lake. Arsenic and Se were detected at relatively low levels for all but Loon Lake where Se was below the analytical detection limit of 0.2 mg/kg.

Sediment subsamples from each lake which had been stored in teflon, were submitted to the IWD National Water Quality Laboratory for a broad spectrum scan of organic contaminants. This work is incomplete at this time.

The shrimp samples (Lepidurus sp.) arrived from the study site by air-freight. Although frozen at the point of departure, the samples thawed in transit. Consequently, analyses have not been conducted for contaminant body burden of the shrimp. These samples have been refrozen and are in storage at the present time.

DISCUSSION

(i) Comparison of field and laboratory data

Differences between field and laboratory pH and specific conductance data

Table 3: Total Metals in Lake Sediments from Truelove Lowlands, Devon Island, NWT

Metal (mg/kg)	Lake Immerk	Loon	Fish	Phalarope
Al	32,700	54,500	51,500	36,800
Cd	< 10.0	< 10.0	< 10.0	< 10.0
Co	< 20.0	< 20.0	< 20.0	< 20.0
Cu	43.3	< 10.0	32.8	18.0
Fe	18,500	29,700	21,200	21,600
Mn	201	614	317	379
Mo	< 50.0	< 50.0	< 50.0	< 50.0
Ni	33.0	< 20.0	< 20.0	22.0
Pb	< 50.0	< 50.0	< 50.0	< 50.0
V	< 100.0	< 100.0	< 100.0	< 100.0
Zn	79.3	51.3	77.2	50.0
Hg	0.05	< 0.02	0.04	0.03
As	3.1	4.1	1.6	2.0
Se	0.8	< 0.2	0.9	0.5

may be due to problems with the field equipment, assuming that the laboratory measurements are the standard with which to conform. Or, changes may have occurred in the samples between the time of sampling and the time of analysis at the laboratory. A line of best fit has purposely not been calculated for these data to avoid any temptation to "correct" what might otherwise be a valid representation of changes in chemistry. As can be seen in Figure 2, there is not a 1:1 correspondence of the field and laboratory measurements of specific conductance. There is evidence of a consistent relationship for the two measurements suggesting a uniform bias with the field SC being higher than the laboratory results by about 50% for all but the first (July 9 - 10, 1985) sample collection when the field results were higher on the average by 135%.

The field and laboratory measurements of pH are compared in Figure 3. The relationship for these results is also shown. In this case, the points cross the 1:1 line with the greatest digression from equivalence occurring in the lower pH ranges. Once again, it is difficult to explain these differences. Conceivably, the field measurements could have been imprecise at the lower pH values, especially since these all occurred at the early part of the study when the personnel may have been less familiar with the instruments. On the other hand, chemical changes may have occurred within the samples during the two to three weeks between sample collection and the measurement of laboratory pH. It is assumed for the purposes of this report that the field pH measurements are accurate and represent the water at the time of sampling.

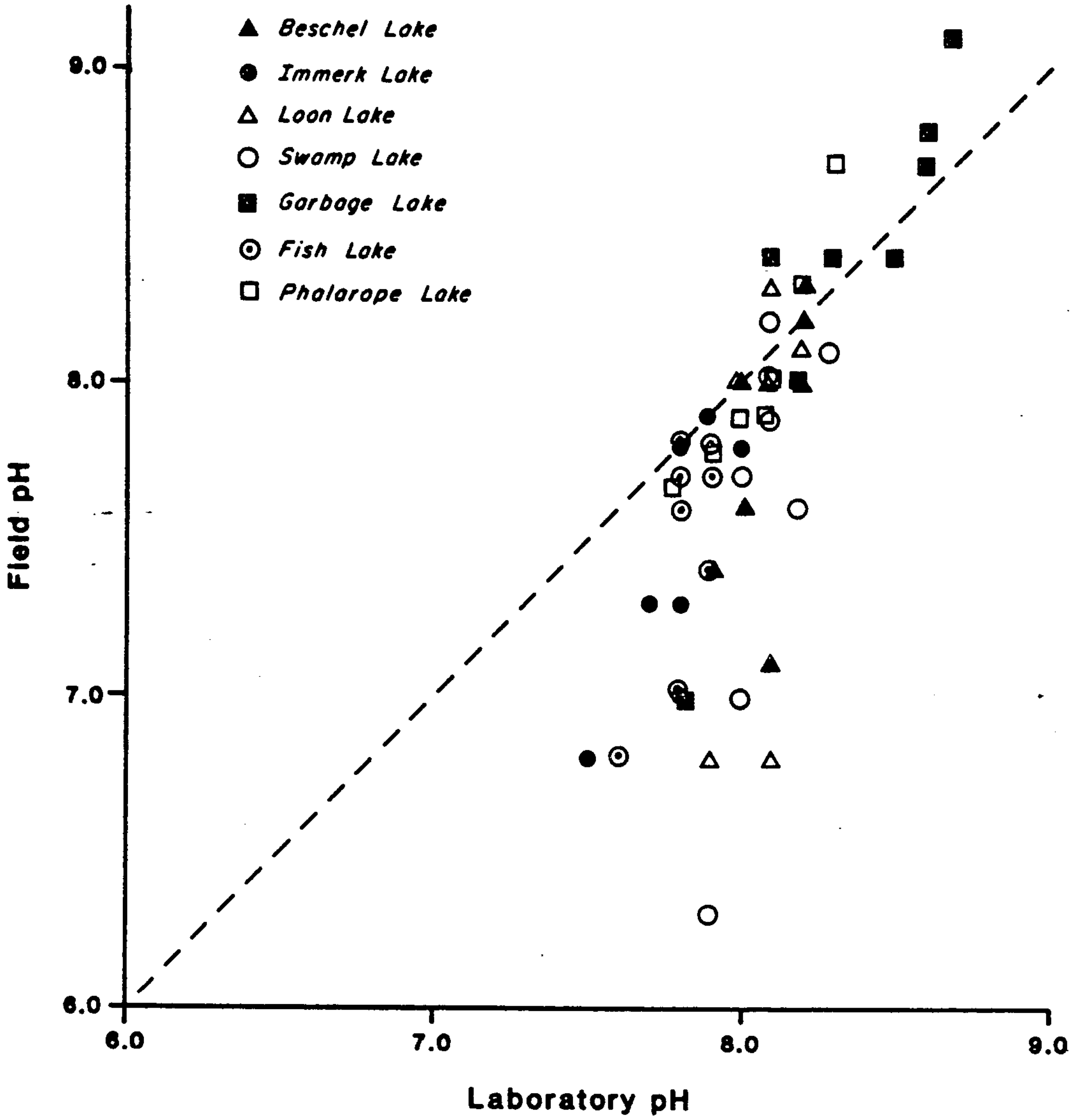

Figure 3. Comparison of Field and Laboratory Measurements of pH.

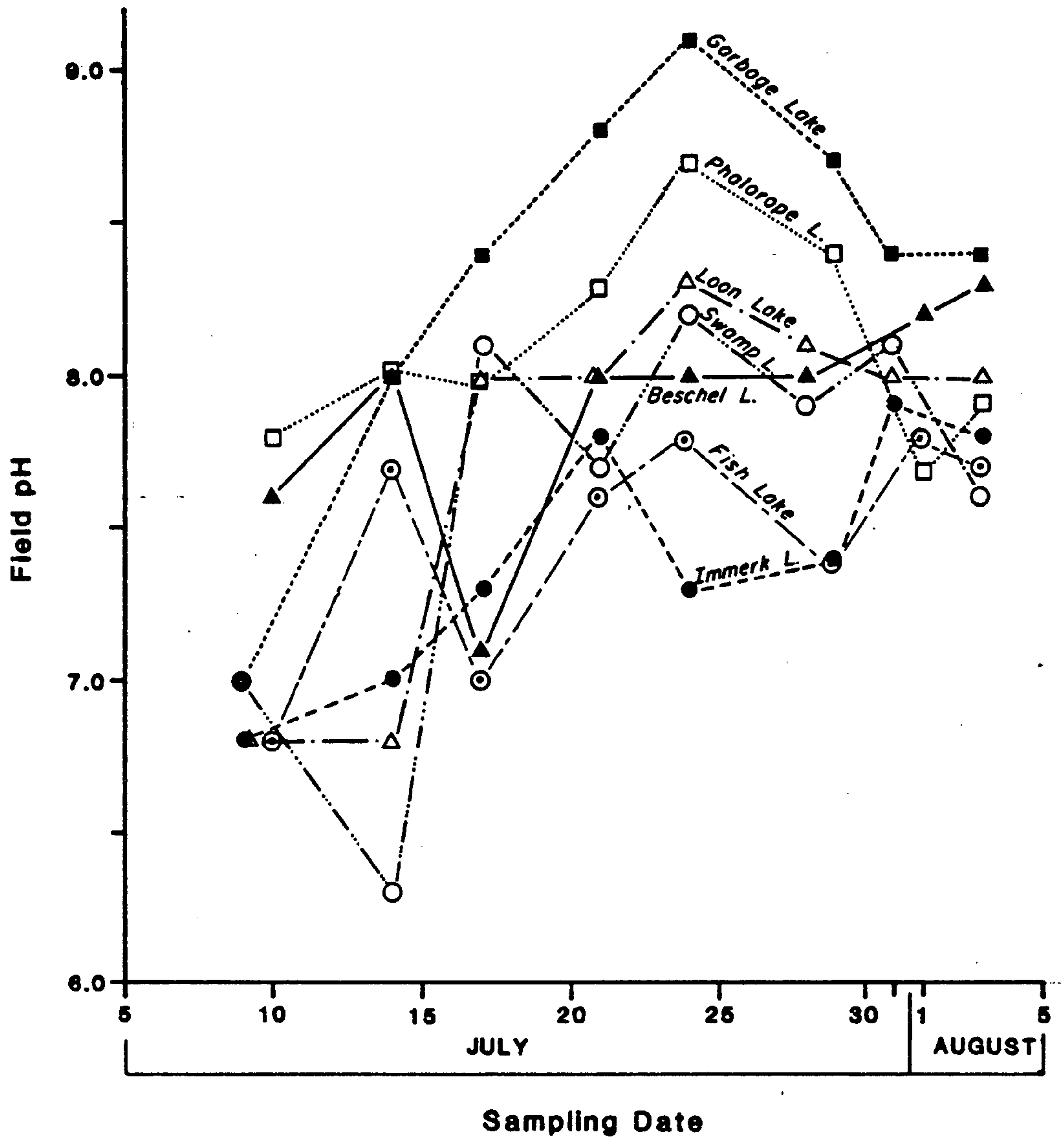

Figure 4. Trends of Field pH, Summer, 1985.

(ii) Acidification

The water chemistry data suggest that these lakes are well buffered against acidification. Using the criteria employed by Tibbatts et. al. (1987) which are > 8 mg/L for Calcium (Ca) and > 20 mg/L for Alkalinity expressed as $CaCO_3$, these lakes would all be considered as "least sensitive". This is entirely consistent with the assessment made of this area using the terrestrial sensitivity classification system (Lucas, 1985).

Despite the lack of apparent sensitivity of these waters, and given that the field pH data are accepted as indicated above, there does appear to be some depression of lake pH early in the snow melting event followed by recovery to what are likely normal pH ranges for these lakes. This trend is apparent for all but Beschel and Phalarope Lakes (Figure 4). Although there is some question regarding the pH data, the trend noted is supported by comparable trends in Alkalinity, bicarbonate (HCO_3) and Ca (Figure 5). Only Phalarope Lake lacks any evidence of a temporal trend for these three parameters. No attempt has been made to quantify these trends or to test them statistically because of the limited data available. The alkaline nature of the lake waters suggest that there is little concern regarding acidification at the present time.

Snow chemistry data for the Truelove Lowlands area for 1985 are not available. Snow samples from two sites to the southwest of this area

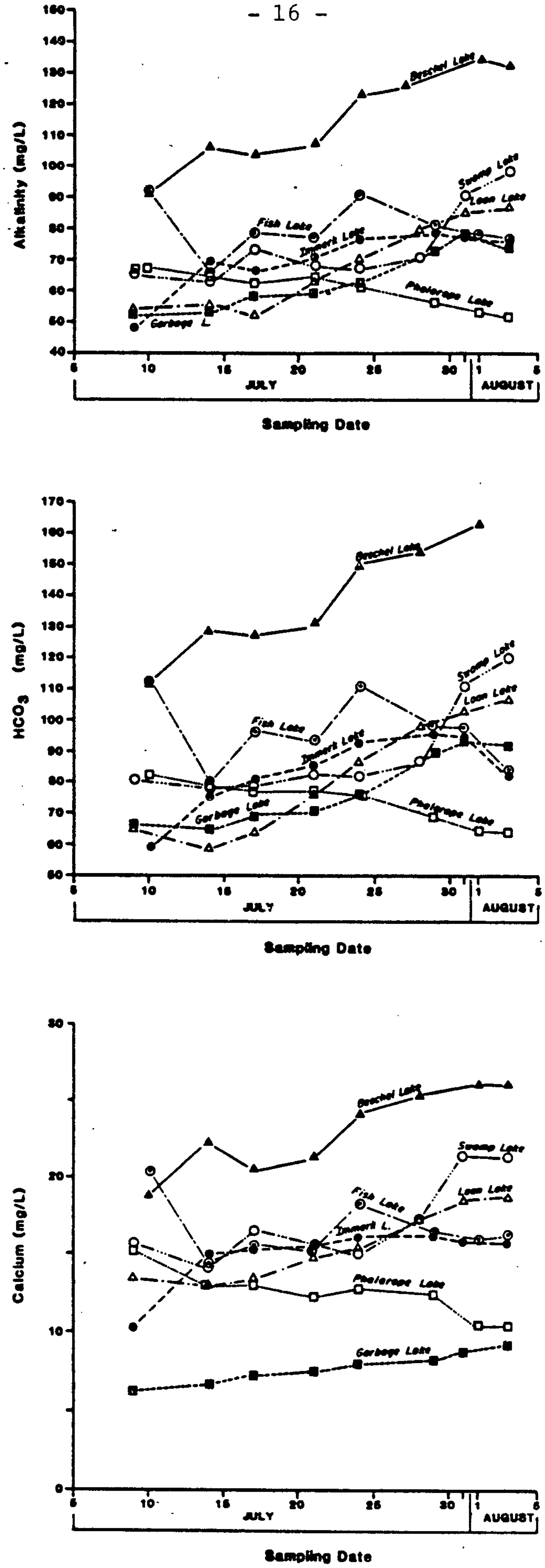

Figure 5. Trends of Alkalinity, HCO_3 and Calcium, Summer, 1985

were collected in May of 1986 (Gregor, 1986a). Field pH for these snow samples (means of 5 replicates in each case) were 7.2 at the Gascoyne well site (74 36.0'N, 91 30.0'W) and 7.7 at the Devon well site (75 04.31'N, 91 48.3'W). The latter site may have been influenced by incorporation of wind blown soil particles in the snow, while the former site may have been influenced by incorporation of sea salt. Interestingly, the laboratory pH values for the snow samples were less at 6.4 and 6.9 for Gascoyne and Devon respectively with the latter being the median of three replicates. These results do not suggest the likelihood of pH suppression in lakes receiving melt waters; however, these samples cannot be assumed to be representative of the Truelove Lowlands or even for the 1985 snowpack.

(iii) Metals in Water

Zinc was commonly detected in the water of all lakes. Iron was detected in all lakes at least once, except for Swamp Lake, but was consistently detected in only Garbage and Phalarope lakes. Snow pack samples from the Gascoyne and Devon well sites for 1986 showed measurable levels of Al, Ba, Cr, Cu, Fe, Mn, Pb, Sr, and Zn (Gregor, 1986b). These data are summarized in Table 4. As and Se were not included in this analyses. McNeely and Gummer (1984) observed only Al, Fe, and Cu above detection in the snow samples (40, 80 and 2 ug/L, respectively) they collected at Cape Herschel. A few of the samples from Cape Herschel contained B and Zn while one sample contained Cd. Barium, Cr, Mn, Pb, and Sr were

Table 4. Metal Chemistry of Snow Samples from Devon Island, May 1986

METAL (mg/L)	GASCOYNE (74° 36.0'N, 91° 30.0'W)	DEVON* (75° 04.3'N, 91° 48.3'W)
Al	0.017	0.038**
Ba	0.011	0.0010
Cd	0.0003	< 0.0001
Cr	0.0009	0.0007
Cu	0.0014	0.0009
Fe	0.022	0.037**
Mn	0.0010	0.0027**
Pb	0.0004	0.0002
Sr	0.0036	0.0024**
Zn	0.0054	0.0012**

Note: Co, Mo, Ni and V were also analyzed but were measured at or below the detection limits of 0.0001 mg/L for Co, Mo and V and 0.0002 for Ni.

* Results for the Devon site are means of four replicates except where the "**" denotes that it is a mean of only three replicates. The latter occurs when an outlier in the first round of analyses was not confirmed in a later set of analyses.

detected at the Devon Island well sites but these parameters had not been analyzed by McNeely and Gummer (1984). Obviously, further studies would be required to make any connection between snow metal chemistry and lake metal chemistry.

(iv) Metals in Sediments

High concentrations are noted for some metals in the bottom sediments of the lakes sampled (Table 1). Upon reviewing the water chemistry data, it is unfortunate that the sediment sampling program did not include Garbage Lake since a wider variety of metals were detected in these waters than in any of the other lakes. There is an absence of information for other lakes in this area for comparison.

(v) Effects of Sediments on Biological Test Populations

Sediment samples for Loon and Fish Lakes were subjected to a bioassay using a technique described by Munawar et al. (1986). The technique is one developed for small sediment samples using a mixed culture phytoplankton population. These bioassays evaluate the nutrient/ contaminant impact (toxicology) of the sediment on laboratory-grown cultures and natural assemblages of algae. The results of the assay are presented in Table 5. Although by no means conclusive, Fish Lake did show a consistent inhibitory effect upon the culture whereas the Loon Lake sediments showed virtually no effect. The cause of this inhibition

Table 5. Bioassessment Results of Loon and Fish Lake Sediments, Truelove Lowlands, Devon Island, NWT

	Treatment	Percent	P Significance
Loon Lake	Water:Sediment	Change	
	76:1	-7.8	< 0.05 *
	36:1	+3.7	> 0.1
	16:1	+3.8	> 0.5
	4:1	+8.8	> 0.2
Fish Lake	76:1	-12.6	< 0.01 **
	36:1	-10.4	< 0.01 **
	16:1	-15.3	< 0.001 ***

Significance: P > 0.05 *
P > 0.01 **
P > 0.001 ***

Note: A negative change implies an inhibitory effect on the phytoplankton whereas a positive change implies no inhibitory effect. The "Treatment" column indicates an increase in sediment concentration as the water sediment ratio decreases.

cannot be attributed solely to the presence of the metals, but the fact that inhibition did occur in one lake suggests that it would be worthwhile to conduct similar tests for the remaining lakes. It will also be important to consider the nutrient chemistry, particularly the phosphorus forms, of these sediments.

SUMMARY AND CONCLUSIONS

Seven lakes in the Truelove Lowlands of Devon Island, NWT, were sampled a total of eight times in the period July 9 to August 3, 1985, for water chemistry, including total metals and major ions. Sediment samples were also collected from four of the lakes for metal and organochlorine analyses. Organochlorine analyses were unavailable at time of writing. Freshwater shrimp collected from three lakes have not been analysed for contaminants because these samples thawed in transport but may be tested in the future if interest warrants.

There are noticeable differences between field and laboratory pH. Similarly, field measurements of specific conductance are considerably and consistently higher than the laboratory measurements. Whether these differences are due to a change in the chemistry of the samples between the time of sampling and analyses at the laboratory or are an artifact of quality control in the field cannot be determined. For the purposes of this report, it has been assumed that the field results are valid; however, caution is advised in their use.

Although the lakes seem to be well buffered and would be considered insensitive to acid deposition by the criteria established for surface waters in the NWT, the field pH measurements suggest that pH is suppressed within a number of the lakes during the snow melt event. The pH recovers quickly to what are probably normal ranges for these lakes. This suppression trend of pH is generally supported by comparable trends for Alkalinity, HCO_3 and Calcium.

Total metals in the water samples are at very low levels. Zinc and Fe were commonly detected. Copper, As and Se were observed infrequently while Pb was observed only once. Aluminum and Fe dominated the sediment samples. Mercury, As and Se were low but detectable in the sediment of most of the lakes.

The sediments from Loon and Fish Lakes were assessed for their toxicity to a mixed culture phytoplankton population. Although not conclusive, Fish Lake sediments show a consistent inhibitory effect whereas Loon Lake sediments showed virtually no effect. Additional bioassays should be undertaken after completion of the organochlorine residue scans and in conjunction with nutrient speciation, to assess the potential effect of atmospherically derived contaminants on lake biota.

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APPENDIX I

1. Water Chemistry Data for selected Lakes from Truelove Lowlands, Devon Island, NWT, July 9 to August 3, 1985.

   - Immerk Lake
   - Loon Lake
   - Swamp Lake
   - Phalarope Lake
   - Garbage Lake
   - Fish Lake
   - Beschel Lake

BESCHEL LAKE, TRUELOVE LOWLANDS, DEVON ISLAND, NWT

DATE	FIELD			LABORATORY (units are mg/L unless indicated)																
	pH (pH units)	S.C. (usie/cm)	Temp (°C)	Alk	Ca	Mg	F	K	Na	Cl	SiO_2	SO_4	pH (pH units)	S.C. (usie/cm)	Turb (NTU)	NFR	HCO_3	Hardness	TDS	Detected Metals
10/07/85	7.6	419	4.	91.5	18.9	10.6	0.046	0.52	1.5	2.0	L0.02	1.3	8.0	171	0.7	1	111.5	90.8	90	Zn=0.001
14/07/85	8.0	325	6.5	105.9	22.2	12.8	0.098	0.56	1.8	2.7	1.53	3.2	8.0	202	0.5	1	129.1	108.1	109	Zn=0.002,Fe=0.04
17/07/85	7.1	325	8.5	104.1	20.7	12.5	0.095	0.55	1.8	2.6	1.53	5.5	8.1	200	0.5	1	126.9	103.2	108	Zn=0.003
21/07/85	8.0	325	10.	107.7	21.4	12.4	0.093	0.52	1.7	2.6	1.50	5.8	8.1	205	0.7	5	131.3	104.5	111	Zn=0.002
24/07/85	8.0	375	9.	123.	24.1	14.0	0.11	0.56	2.0	2.9	1.78	2.3	8.0	222	0.5	1	149.9	117.8	122	Zn=0.002
28/07/85	8.0	400	12.	126.	25.3	14.5	0.11	0.67	2.1	3.1	1.83	2.3	8.1	240	0.5	1	153.6	122.9	126	
01/08/85	8.2	375	11.	134.	26.1	14.9	0.12	0.60	2.3	3.0	1.83	2.3	8.2	247	0.6	1	163.3	126.5	132	Zn=0.002
03/08/85	8.3	400	8.	133.	26.1	15.0	0.12	0.81	2.2	3.1	1.76	2.7	8.2	241	0.6	1	162.	126.9	132	Cu=0.001,Zn=0.002

IMMERK LAKE, TRUELOVE LOWLANDS, DEVON ISLAND, NWT

DATE	FIELD			LABORATORY (units are mg/L unless indicated)																
	pH (pH units)	S.C. (usie/cm)	Temp (°C)	Alk	Ca	Mg	F	K	Na	Cl	SiO_2	SO_4	pH (pH units)	S.C. (usie/cm)	Turb (NTU)	NFR	HCO_3	Hardness	TDS	Detected Metals
09/07/85	6.8	397	1.	48.9	10.4	5.3	0.036	0.43	3.2	5.0	0.31	0.5	7.5	169	0.6	2	59.6	47.8	55	Zn=0.005,Fe=0.05
14/07/85	7.0	225	6.5	69.7	15.0	7.9	0.03	0.6	4.8	8.8	0.4	2.5	7.8	155	0.3	1	75.5	70.	82	Cu=0.001,Zn=0.001
17/07/85	7.3	310	7.5	67.8	15.3	8.0	0.03	0.6	4.8	8.4	0.5	0.9	7.7	190	0.3	1	81.	71.1	79	Zn=0.002
21/07/85	7.8	250	7.0	71.3	15.6	8.2	0.03	0.6	5.1	8.8	0.39	0.9	7.8	171	0.2	L1	85.3	72.7	82	
24/07/85	7.3	210	10.	76.5	16.1	8.1	0.03	0.55	5.2	9.1	0.41	0.7	7.8	187	0.3	L1	93.3	73.5	86	Zn=0.002
29/07/85	7.4	260	7.	78.7	16.3	8.4	0.04	0.53	5.3	9.3	0.39	1.4	7.9	169	0.3	L1	95.9	75.3	89	Cu=0.002,Zn=0.002
31/07/85	7.9	225	8.	77.7	15.9	8.4	0.03	0.52	5.3	9.3	0.42	1.1	7.9	171	0.4	1	94.7	74.3	88	Zn=0.002
03/08/85	7.8	250	15.	75.5	15.9	8.1	0.03	0.5	5.3	9.4	0.4	1.6	8.0	172	0.3	L1	82.5	73.1	87	Zn=0.001,Fe=0.04 As=0.0001

LOON LAKE, TRUELOVE LOWLANDS, DEVON ISLAND, NWT

DATE	FIELD			LABORATORY (units are mg/L unless indicated)																
	pH (pH units)	S.C. (usie/cm)	Temp (^oC)	Alk	Ca	Mg	F	K	Na	Cl	SiO_2	SO_4	pH (pH units)	S.C. (usie/cm)	Turb (NTU)	NFR	HCO_3	Hardness	TDS	Detected Metals
09/07/85	6.8	331	2.	53.6	13.4	5.5	0.029	0.17	0.5	0.7	0.47	0.7	7.9	107	0.9	2	65.3	56.1	54	Zn=.001,Fe=.04
14/07/85	6.8	180	7.	56.3	13.0	5.5	0.01	0.2	0.6	0.9	0.5	2.5	8.1	105	0.7	1	59.1	55.1	57	Zn=0.002
17/07/85	8.0	160	11.	52.7	13.4	5.7	0.020	0.18	0.5	0.9	0.45	2.6	8.0	111	0.7	1	64.2	56.9	55	
21/07/85	8.0	190	9.	64.1	14.9	6.6	0.02	0.2	0.6	0.9	0.5	0.8	8.1	122	0.6	1	76.5	64.4	63	Zn=.002
24/07/85	8.3	200	11.5	70.1	15.4	6.5	0.03	0.22	0.6	1.6	0.50	1.7	8.1	128	0.3	L1.0	85.5	65.2	69	Zn=0.001
28/07/85	8.1	200	14.	79.6	17.1	7.8	0.03	0.36	4.5	7.7	0.59	2.1	8.2	145	0.4	L1.0	97.	74.8	88	Pb=.001,Zn=.003, Fe=.07
31/07/85	8.0	225	9.	84.6	18.7	8.2	0.03	0.24	0.7	1.3	0.65	1.1	8.1	159	0.5	1.0	103.1	80.5	82	Zn=.001
03/08/85	8.0	250	8.	86.6	18.9	8.3	0.03	0.25	0.9	1.4	0.63	1.4	8.2	163	0.5	L1.0	105.6	81.4	84	Zn=0.003

SWAMP LAKE, TRUELOVE LOWLANDS, DEVON ISLAND, NWT

DATE	FIELD			LABORATORY (units are mg/L unless indicated)																
	pH (pH units)	S.C. (usie/cm)	Temp (°C)	Alk	Ca	Mg	F	K	Na	Cl	SiO_2	SO_4	pH (pH units)	S.C. (usie/cm)	Turb (NTU)	NFR	HCO_3	Hardness	TDS	Detected Metals
09/07/85	7.0	306	6.0	66.2	15.9	6.4	.029	0.19	0.6	0.9	0.41	0.4	8.0	123	0.9	2	80.7	66.1	65	Zn=0.001
14/07/85	6.3	190	7.5	64.1	14.5	6.1	0.02	0.2	0.6	0.9	0.4	2.6	7.9	108	0.5	1	78.1	61.5	64	Zn=.002
17/07/85	8.1	200	11.5	74.2	16.6	7.1	.03	0.2	0.7	0.8	0.6	0.2	8.3	136	0.6	1	88.8	70.7	71	Zn=.002
21/07/85	7.7	175	9.	69.1	15.6	6.8	.02	0.2	0.6	0.9	0.5	0.3	8.0	122	0.4	1	82.6	66.9	66	Zn=.003
24/07/85	8.2	200	11.5	67.0	15.1	6.8	.03	.34	4.6	7.7	.45	2.0	8.1	130	0.4	L1	81.7	65.7	75	Zn=.004
28/07/85	7.9	220	14.	71.0	17.2	7.4	.03	.23	0.9	1.4	.59	1.9	8.1	145	0.4	1	86.5	73.4	72	Zn=.002
31/07/85	8.1	280	9.	91.3	21.6	8.2	.03	.24	0.8	1.5	.78	1.2	8.1	176	0.6	1	111.3	87.7	89	As=0.0001,Zn=.003
03/08/85	7.6	260	7.	98.5	21.4	9.2	.03	.23	0.8	1.4	.69	1.7	8.2	176	0.3	L1.0	120.1	91.3	95	Zn=0.001

GARBAGE LAKE, TRUELOVE LOWLANDS, DEVON ISLAND, NWT

DATE	FIELD			LABORATORY (units are mg/L unless indicated)																
	pH (pH units)	S.C. (usie/cm)	Temp (^{o}C)	Alk	Ca	Mg	F	K	Na	Cl	SiO_2	SO_4	pH (pH units)	S.C. (usie/cm)	Turb (NTU)	NFR	HCO_3	Hardness	TDS	Detected Metals
09/07/85	7.0	291	8.	53.6	6.2	9.7	.024	.60	7.5	16.7	0.10	1.5	7.8	146	0.4	1	65.3	55.4	74.	Zn=.004 V=.0006,Fe=0.10
14/07/85	8.0	250	9.5	53.1	6.8	11.1	.030	0.70	9.0	20.2	0.1	0.4	8.2	169	0.3	L1	64.7	62.5	80	Zn=.003,Fe=0.06
17/07/85	8.4	290	13.	58.4	7.2	11.9	.02	0.8	9.6	21.5	0.2	0.3	8.5	176	0.3	1.0	69.6	67.	87	Cu=.004,Zn=.003 Fe=.05
21/07/85	8.8	290	9.5	59.5	7.6	12.6	.02	0.8	10.4	22.6	0.2	0.5	8.6	188	0.3	1.0	70.9	70.9	90	Cu=.001,Zn=.003 Fe=.05
24/07/85	9.1	320	11.5	62.8	8.0	12.4	.03	0.83	10.6	23.1	.33	1.9	8.7	194	0.3	1.0	76.6	71.	95	V=.0005,Fe=.04 As=.0001,Se=.0001
29/07/85	8.7	350	10.	73.7	8.4	13.4	.03	.90	11.3	24.3	.33	1.8	8.6	205	0.7	–	89.8	76.1	105	Cu=.002,Zn=.002 V=.0008,Fe=.04
31/07/85	8.4	350	8.	77.3	8.9	13.8	.03	.88	34.8	25.2	.43	0.9	8.1	214	0.7	2	94.2	79.	131	Zn=.003,V=.0011 Fe=.09
03/08/85	8.4	280	14.	75.2	9.2	14.1	.04	.90	20.8	25.7	.53	1.0	8.3	219	0.6	1	91.7	81.	117	Zn=.001,V=.0007 Fe=.07,As=.0001

FISH LAKE, TRUELOVE LOWLANDS, DEVON ISLAND, NWT

DATE	FIELD			LABORATORY (units are mg/L unless indicated)																
	pH (pH units)	S.C. (usie/cm)	Temp (^{o}C)	Alk	Ca	Mg	F	K	Na	Cl	SiO_2	SO_4	pH (pH units)	S.C. (usie/cm)	Turb (NTU)	NFR	HCO_3	Hardness	TDS	Detected Metals
10/07/85	6.8	497	3.	92.4	20.3	10.5	.096	.63	5.4	9.7	.49	1.8	7.6	190	0.5	1	112.6	93.9	104	Zn=.002,Se=.0001
14/07/85	7.7	240	4.	65.9	14.3	8.0	.021	.5	4.0	7.8	.5	5.8	7.8	149	0.4	1	80.3	68.5	81	Zn=.001,Fe=0.04
17/07/85	7.0	250	8.	78.5	16.2	9.0	.023	.6	4.6	8.8	.4	6.6	7.8	171	0.3	L1	95.7	77.5	93	Zn=.002,
21/07/85	7.6	290	9.5	77.8	16.1	8.9	.02	.6	4.6	8.5	.4	.8	7.8	183	.3	L1	93.2	76.8	87	Zn=.002
24/07/85	7.8	260	9.0	90.9	18.4	9.8	.03	.61	5.2	9.7	.44	1.5	7.8	168	.3	L1	110.8	86.3	100	Zn=.001
29/07/85	7.4	260	7.0	81.1	16.3	8.6	.03	.53	4.6	8.7	.44	0.9	7.9	171	.3	L1	98.9	76.1	89	Zn=.003
01/08/85	7.8	275	10.5	79.2	16.0	8.5	0.03	.51	4.6	8.4	.37	1.1	7.9	170	.5	L1	96.5	74.9	87	Zn=.002,Fe=.06
03/08/85	7.7	270	8.0	76.5	16.4	8.6	.03	.5	4.7	8.4	.5	2.1	7.9	164	.5	L1	83.7	76.4	87	Cu=.001,Zn=.003 Fe=.07

PHALAROPE LAKE TRUELOVE LOWLANDS, DEVON ISLAND, NWT

DATE	FIELD			LABORATORY (units are mg/L unless indicated)																
	pH (pH units)	S.C. (usie/cm)	Temp (^oC)	Alk	Ca	Mg	F	K	Na	Cl	SiO_2	SO_4	pH (pH units)	S.C. (usie/cm)	Turb (NTU)	NFR	HCO_3	Hardness	TDS	Detected Metals
10/07/85	7.8	300	3.	67.4	15.2	9.4	.03	.8	8.4	16.7	0.3	2.6	7.9	195	0.3	L1.0	82.2	76.5	94	Zn=.002,Fe=0.10
14/07/85	8.0	250	3.5	64.0	13.0	8.2	.02	.8	7.4	14.4	0.5	1.7	8.1	170	0.3	L1	78.	66.5	85	Zn=.001,Fe=0.09
17/07/85	8.0	250	9.	63.0	13.4	8.6	.031	0.74	7.4	14.3	.68	2.2	8.1	170	0.3	L1	76.8	68.9	85	Zn=.004,Fe=.08
21/07/85	8.3	250	8.5	63.9	12.3	7.9	.03	0.7	7.2	13.6	0.2	1.2	8.2	158	0.3	L1	76.3	63.2	81	Zn=.003,Fe=.07
24/07/85	8.7	225	10.0	62.	12.9	12.1	.04	2.2	50.3	91.7	.19	11.8	8.3	151	.3	L1	75.6	82.0	218	Fe=.07
29/07/85	7.9	210	6.5	55.7	12.3	6.4	.03	.53	6.0	11.1	.24	2.0	8.1	133	.4	1	67.9	57.1	72	Zn=.003,Fe=0.10
01/08/85	7.7	220	11.0	53.1	10.6	6.5	.03	.52	6.2	11.2	.17	1.9	7.8	136	.9	1	64.7	53.2	69	Fe=0.15
03/08/85	7.9	210	8.0	52.4	10.5	6.5	.03	.54	6.2	11.3	.20	2.0	8.0	138	.7	1	63.9	53.0	69.0	Zn=.002,Fe=0.12

Date Due
